National Bureau of Standards

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High-Speed Crystal Clutch

AN experimental crystal clutch recently developed at the National Bureau of Standards is believed to be the first of its type. In the new clutch, application of a direct-current voltage to the electrodes of three "Bimorph" piezoelectric crystal elements causes bending of the elements; this bending presses the clutch output disk against the rotating input disk. The new experimental unit was devised by Ernest Codier of the NBS staff as part of a program for the development of fast-acting clutches suitable for use in high-speed computers.

Distinguishing features of the crystal clutch are high speed of response and almost negligible current drain. No current flows, other than insulation leakage, after the applied voltage has charged the capacity of the crystals. The clutch therefore creates no magnetic field, an advantage in some applications.

In the only clutch model thus far constructed, the output shaft delivered useful torque in as little as 0.2 millisecond after voltage was applied. Output torque of the engaged clutch was approximately 16.5 ounce-inches at 400-volts excitation, or 21 ounce-inches for 500 volts. The no-voltage drag torque, however, was about 7.5 ounce-inches, a substantial fraction of the engaged torque.

Construction of the crystal clutch is essentially simple. The output disk is located between two rotating members: a thin, flexible crystal pressure plate and a heavier mounting plate, or input disk. Three of the Bimorph crystal elements, which bend when opposite potentials are applied to different parts of the crystal surfaces, are spaced at 120° intervals. When the exciting voltage is applied, the crystals press against the pressure plate at a radius of 1.5 inches, pinching the output disk between the pressure plate and the input disk.

The clutch proper and its immediate mounting occupy a space about 6 inches in diameter and a little more than an inch long. The complete assembly includes, in addition, internal bearings for the output shaft, bearings and mounts for the entire assembly, a drive pulley, and slip rings for transmitting the exciting voltage to the rotating assembly.

The new clutch was tested for speed of response by placing the needle of an ordinary crystal phonograph pickup in a small dimple in the clutch output shaft. By connecting the pickup output to the vertical input of a cathode-ray oscilloscope, and connecting the clutch excitation voltage to the horizontal input, the time lag between the application of the exciting voltage and the resulting motion of the output shaft was observed. Alternatively, by connecting the Bimorph terminals to the vertical plates of the oscilloscope, it was possible to observe the voltage rise as the capacitance of the Bimorph crystals became charged.

Several factors enter into the design of a clutch of this type. Speed of response, the principal design goal, is related to the inertia and loading of the output system, the available torque, the distance the crystal pressure point must move before it begins to pinch the output disk, and the resonant frequency of the crystal itself. It is the resonant frequency that sets the ultimate limit for speed of response.

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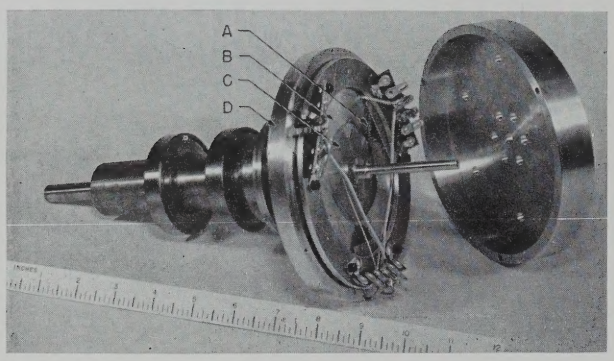


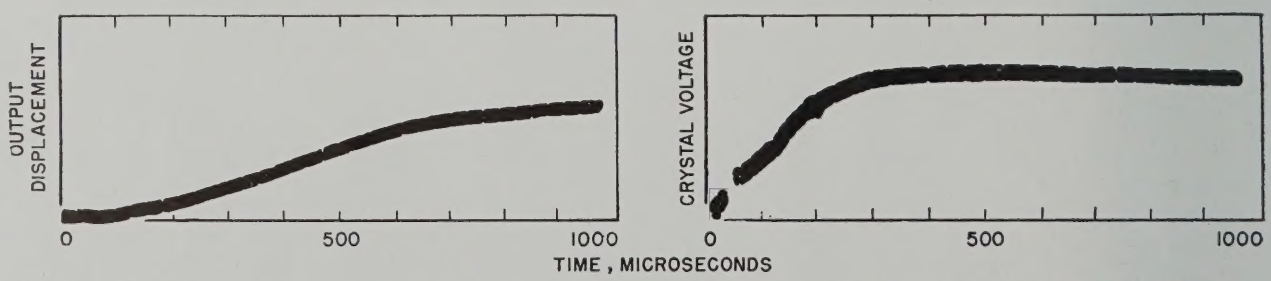
Three Bimorph crystal elements, which bend when a direct-current voltage is applied, form the basis of the NBS crystal clutch. Bending of the elements (*A*) pinches the output disk (*C*) between the rotating crystal pressure plate (*B*) *and the rotating mounting* plate (*D*).

The dimensions of the Bimorph crystal determine not only its resonant frequency but also its sensitivity. The resonant frequency, in kilocycles, of a Rochelle-salt crystal Bimorph is given by $26\ T/LW$, and the sensitivity in mils per kilovolt is approximately $0.08\ LW/T^2$, where L, W, and T are crystal length, width, and thickness, in inches. Since increased crystal thickness is favorable to high resonant frequency but unfavorable to high sensitivity, design dimensions must be matters of compromise and judgment.

If resistance is present in the excitation circuit, the voltage appearing across the crystals will rise exponentially while the crystal capacity (about 0.0065 microfarad) is charged. If the voltage rise is excessively slow, speed of response will of course be impaired. It might be thought that if resistance were eliminated, so as to give very fast voltage rise, speed of response would be a maximum. This does not prove to be the case, however. Instead, an irregular output motion appears, probably due to bouncing of the crystal against the output disk, while response time shows no significant improvement.

Rochelle-salt crystal elements are used in the present clutch because they are readily available and highly sensitive. Rochelle salt has several disadvantages, however: it is easily fractured, melts at 55° C, and will deliquesce unless protected from humidity. Barium titanate crystals, a logical alternative, should provide a mechanically rugged clutch usable at temperatures up to 100° C. Barium titanate is less sensitive than Rochelle salt, however, and also has a higher capacity.

Obviously, the crystal clutch developed at NBS does not have wide applicability. Yet its high speed and negligible current drain could be very valuable in a few highly specialized but nevertheless important instrumentation functions. In special photographic recording apparatus, for instance, the crystal clutch could be used to move motion picture film in fast response to an actuating voltage. The experimental clutch model could undoubtedly be improved upon; in fact, several desirable modifications have already become apparent.



The rapid response of the crystal clutch can be seen from the oscilloscope trace of output displacement against time. The trace is obtained by placing the needle of a phonograph pickup in a small depression on the output shaft; the pickup output is then connected to the vertical plates of the oscilloscope, and the excitation voltage to the horizontal plates. The crystal voltage trace, obtained by connecting the Bimorph terminals to the vertical plates, indicates the voltage rise as the capacitance of the Bimorph crystal becomes charged.

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U. S. Department of Commerce

Charles Sawyer, *Secretary*

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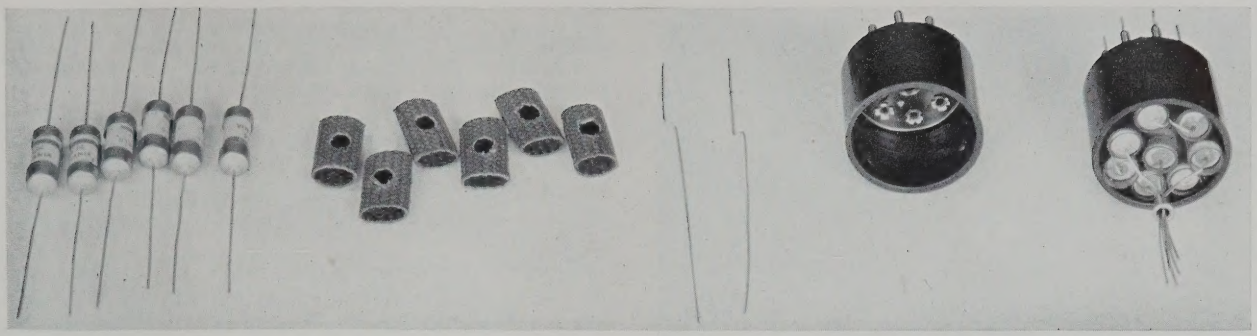


More than 16,000 germanium diodes are used in SEAC, the National Bureau of Standards Eastern Automatic Computer, for computing and switching. They are mounted in plug-in bases to facilitate insertion and removal. SEAC is a natural proving ground for the diodes, because it requires extremely high reliability.

Germanium Diode Experience in the SEAC Program

UNITED STATES production of germanium diodes for radio and electronic applications has expanded to something like 4 million a year. Yet because they are relatively new, germanium diodes have not received extensive service study, and few significant data on their characteristics in extended use have become available. Because it uses some 16,000 germanium diodes for computing and switching functions, with the requirement of very high reliability, the National Bureau of Standards Eastern Automatic Computer (SEAC) is a natural proving ground for the diodes. Of interest, therefore, is a recent preliminary study of experience with germanium diodes in the SEAC program. Conducted by J. H. Wright of the NBS electronic computers laboratory, the study is based on data compiled during the electronic computer's first 6 months of operation after its dedication in June 1950.

Reliability is the outstanding requirement of diodes in computer use. Even momentary failure of a single one of SEAC's diodes will cause computer misfunction.

In view of this severe requirement, germanium diode experience in the SEAC program has been gratifying. After some 2,500 hours under voltage, only about 5 percent of the diodes initially in service had had to be replaced, the rest of the replacements being because of back current drift, or "creep." The great majority of these replacements were made in the course of routine maintenance checks before the questionable diodes could cause computer misfunction. Also encouraging, the rejection rate for the several thousand diodes purchased in the last 6 months of 1950 was less than 2 percent. Moreover, diode quality has undoubtedly improved since SEAC's first diode purchases were made, and continued improvement seems likely.

SEAC circuitry was designed to use diodes of a single specification, the 50 volts (back) 50 milliamperes (forward) type, such as Sylvania IN34 and IN34A, Kemtron IN34, Raytheon CK705, and General Electric IN48 and IN69. A design value of -40 volts was selected as being the absolute limit of back voltage that would be encountered, and 20 milliamperes was chosen arbitrarily as the peak forward current.

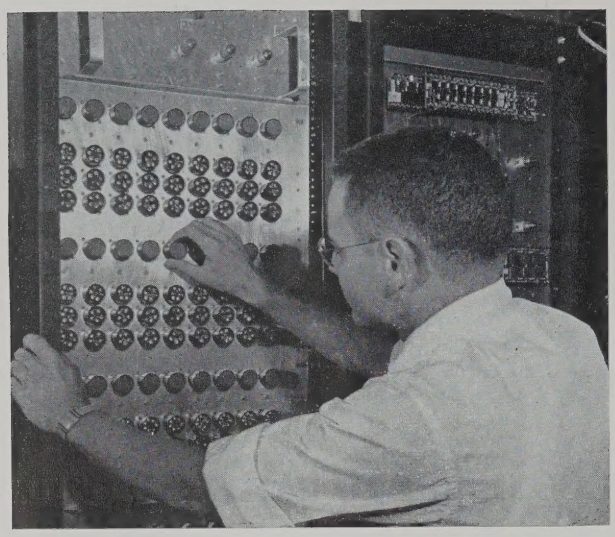
Each diode must be individually tested before use in SEAC; spot checking is inadequate, since all weak links must be excluded. Tests are made twice before a diode goes into service, once before soldering into position and once after. Equally important to reliable computer function are the preventive maintenance checks made at regular intervals on diodes already in service.

SEAC diodes are tested for back current at -40 volts and forward voltage drop at 20 milliamperes forward current, the design maxima. For a "normal" diode, that is, one that does not "creep" appreciably, permissible back current at -40 volts is specified as 250 microamperes before soldering, 300 microamperes after soldering, and 500 microamperes for units in service. For a "good creeper," corresponding rejection limits are 120, 200, and 300 microamperes. (A good creeper is defined as one that drifts less than 50 microamperes and stabilizes markedly in the half-minute observation period.) Rapid "wigglers" (rapidly fluctuating creepers, with periods of less than a second) must not exceed plus or minus 10 microamperes fluctuation. Maximum permissible forward voltage at 20 milliamperes is 2.0 volts before or after soldering and 2.3 volts for units in service. Fixed forward current was specified rather than fixed voltage,

Diode failures in SEAC service, June 1 to November 1, 1950 (approximately 2,500 hours under voltage)

	Number replaced	Percentage of total diodes [a] (12,000)
		Percent
Failures detected during computer breakdown	50	0.42
Replacements after routine checks:		
Excessive back current (i_b)	64	.53
Excessive forward voltage (e_f)	23	.19
Drift	154	1.23
Open	2	.02
Unspecified	353	2.9
Total	596	5.0

[a] Subsequent additions to SEAC circuitry have increased the total number of diodes by several thousand.



All computing and switching in SEAC are done by germanium diodes rather than by electron tubes. A typical subassembly contains a large number of germanium diode units.

partly because SEAC's gate circuits are current operated, and partly because the fixed-current test circuit is short-circuit proof.

Deterioration of back characteristics has been the chief reason for SEAC diode replacements; and excessive creep has been a much more frequent reason for replacement than excessive back current. Excessive creepers are replaced because of their unpredictability, although creep of itself will not necessarily cause computer misfunction. Creep in back current was observed in a substantial percentage of the commercially available diodes tested for SEAC, including both the wax imbedded types and the hermetically sealed types without the wax embedding. The incidence of creep varied between makes, however, as well as from batch to batch. Forward characteristics, unlike back characteristics, deteriorated very little; and the number of complete failures such as shorts and opens was negligible.

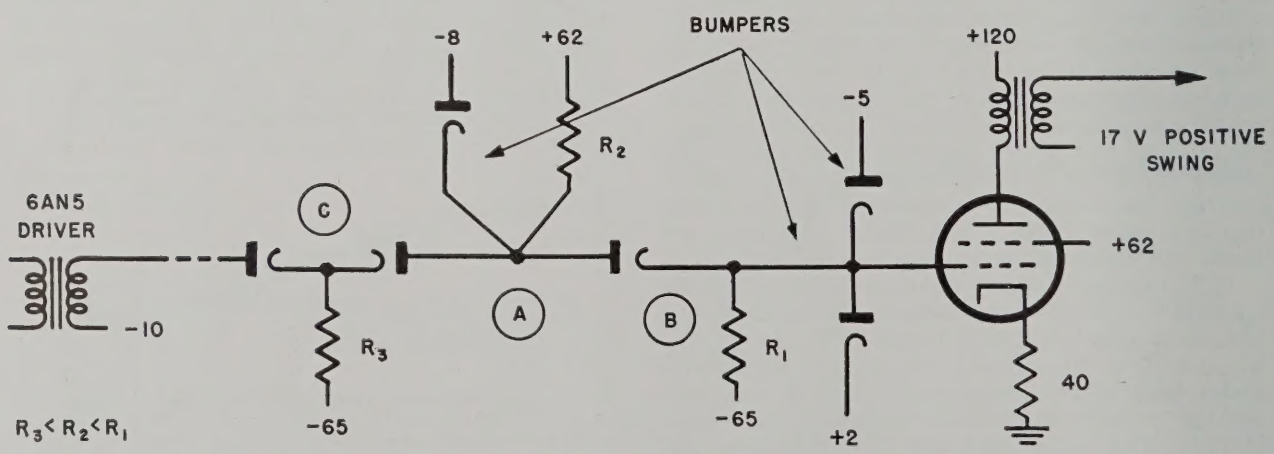
Creep in diodes has not been fully described or theoretically explained in the literature. The SEAC study provides a substantial amount of data concerning this troublesome phenomenon. This information in turn affords some basis for speculation as to the mechanism of creep, although theory was not the primary concern of the study.

Creepers vary widely in their behavior. Initial creep may be in the direction of either increased or decreased current, while the long-term trend may bear no relation to the initial trend. Initial downdrifters are at present considered as undesirable as updrifters, since either seems likely to rise to excessive currents in the course of time. Creep may be gradual and steady, perhaps ultimately leveling off. Or, as more often happens, it may be more or less periodic, the period varying widely from less than a second ("wigglers") to a number of minutes or even hours.

It now seems clear that diode creep is not caused to any appreciable extent by imperfect mechanical contact. Although moisture is suspected of playing some role, it appears unlikely that some of the observed creep phenomena could be caused by moisture alone. Peculiarities in the germanium structure in the neighborhood of the contact, with sensitivity to small temperatures or to electric fields, would seem to be another possibility. Further work on the heat treatment of the germanium ingots, and on the forming of the diodes, may help to explain and solve the creep problem.

In addition to the observations on diodes in regular service, a few experiments were made. To study the effect of operating temperature on creep, 29 creepers were tested at 25° and 75° C. Although individual units differed, these experiments indicate that drift is not notably aggravated by increase in temperature within the usual operating range.

Another group of 18 creepers was studied for 210 hours at room temperature in an effort to determine whether an observation of 1 minute or less is sufficient to exclude long-term creepers. These limited data indi-



Basic diode switching circuit used in SEAC. Additional *and* inputs may be tied at *A*; additional *or* inputs may be tied at *B* or *C*.

cate that 1-minute or one-half-minute observations, holding to a 300-microampere limit, satisfactorily exclude those units that would later drift beyond 500 microamperes.

Pursuing the theory that creep might be related to moisture contamination, some experiments were run in which several makes of diodes were subjected to water soaking at room temperature. The chief effect of soaking (on nonhermetically sealed units) was to raise the back current and produce "jumping"; the back current at −40 volts would rise to at least 1,000 microamperes and frequently to 2,500 microamperes, and would swing in an erratic fashion back and forth over a range of several hundred microamperes, the swing taking from 1 to 5 seconds.

Experimental attempts were made to salvage some of the water-soaked diodes, either by baking or with heavy forming currents similar to those used in the original manufacture. Both treatments were distinctly beneficial. When the heavy-current salvage treatment was tried on creepers rejected for SEAC use, great improvement was noted in about one-third of the rather small number treated, while the other two-thirds deteriorated. Limited though these soaking and salvage data are, they point to the possibilities of, first, salvage of rejected diodes, and second, manufacture of more stable diodes by increased pulse forming treatment and perhaps by baking.

The SEAC diode experience study indicates a definite need for more life data and better specifications for germanium diodes for computer applications. NBS investigators have outlined data-compilation and specification projects that they hope will be undertaken cooperatively by computer groups and other interested diode users.

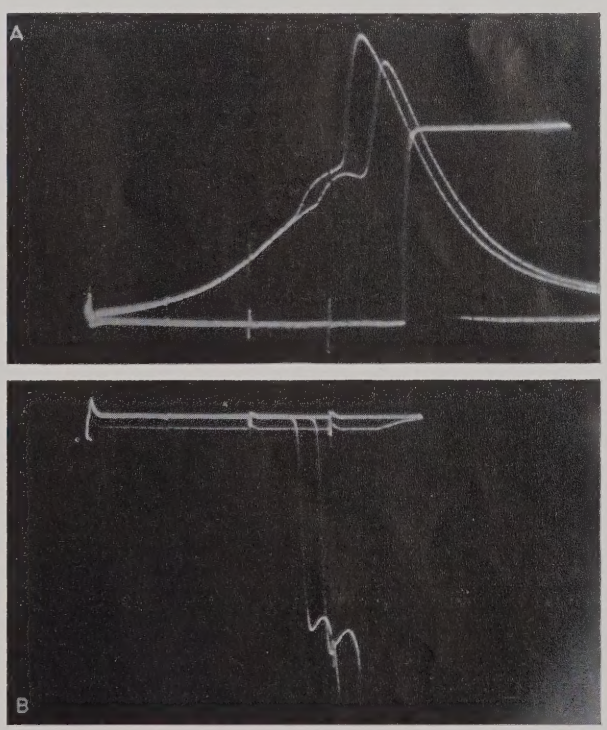
For further information on the NBS computer, see SEAC, the National Bureau of Standards Eastern Automatic Computer, *NBS Tech. News Bull.* **34**, *121 (1950)*. *See also* SEAC demonstrates high reliability, *NBS Tech. News Bull.* **35**, *72 (1951)*.

Research on Engine Knock

INCREASED understanding of the mechanism by which "knock" is produced in automotive engines has resulted from compression-ignition studies now under way at the National Bureau of Standards. This work, conducted by W. J. Levedahl and F. L. Howard of the NBS engine fuels laboratory, employs a single-cylinder test engine of variable compression ratio in which a wide range of operating conditions may be simulated. Oscillograph traces showing pressure change and light emission during combustion in the test engine provide an insight into the nature of knock and can be used to correlate knocking characteristics of fuels with their chemical structure.

With the present rapid increase in the number of automotive units in use in this country, problems of fuel conservation are becoming more and more important. Probably the best single way to reduce fuel consumption in the automotive engine is to increase its compression ratio, which means in effect increasing the pressure at which the fuel is burned in the combustion chamber. This raises the temperature of combustion and hence raises the amount of heat energy per unit of fuel that is made available to do work. However, if the compression ratio is increased beyond the limit allowed by the fuel, detonation (or knock) occurs, with consequent loss in power and possible damage to the engine. Although this problem has been recognized for many years, it is still only partially understood.

Investigators have found that in normal, nonknocking combustion, the flame initiated at the spark plug travels evenly across the combustion chamber, generating pressure, which pushes the piston down. In knocking combustion, the flame progresses for a time in the



Two combustion stages in autoignition of "end-gas" are revealed by oscillograms of (*A*) pressure in the combustion chamber and (*B*) light emission, both plotted against crankshaft rotation (or piston travel). *A*: Small humps represent the first stage; the succeeding large increase marks the beginning of the second stage, during which knock occurs. *B*: Light emitted by the reaction first increases and then decreases during the first stage. This is followed by a strong increase in light emission during the second stage.

same way, burning most of the charge evenly. Ultimately, however, some of the unburned charge, known as the "end gas," is compressed to a high pressure, which causes it to ignite spontaneously (autoignite) and to burn with explosive violence. The sudden release of energy acts as a hammer blow on the piston, rather than a gradual push, and a shock wave is initiated that is reflected back and forth across the combustion space. A large portion of the energy released in this way is not converted to power but causes a wasteful increase in temperature.

Seeking further information on the basic nature of detonation, the National Bureau of Standards is studying the conditions prevailing in the end gas. To provide the necessary data, apparatus has been constructed in which the end gas is simulated. In this apparatus, a mixture of fuel and air is inducted into a single-cylinder test engine, which is driven by an electric motor known as a dynamometer. Here the piston compresses the mixture to the conditions of temperature and pressure under which autoignition takes place. The pressure in the cylinder acts on a strain-gage pressure pickup, which is connected through a bridge circuit and amplifier to an oscilloscope. The pressure is thus shown on the oscilloscope as a function of crank angle, or time. At the same time, the light emitted by the autoignition is picked up by a photomultiplier tube, which amplifies it and makes another trace on an oscilloscope.

The engine used in the NBS studies is a modified ASTM supercharge aviation-method fuel-rating engine. By removing the springs beneath the cylinder and changing the zero setting on the micrometer used to measure the cylinder height, compression ratios in excess of 18:1 have been made possible. The dynamometer maintains engine speed at 600, 900, 1,200, or 1,800 rpm. The temperature of the cylinder jacket can be maintained constant at any temperature between 150° and 212° F.

Two Stages in Autoignition

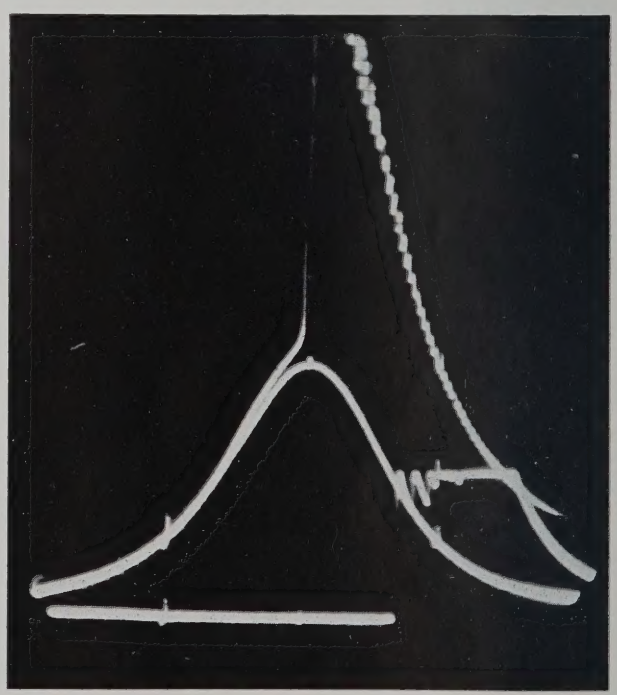
From the NBS study, two distinct stages in autoignition have been recognized. In the first stage a low-intensity blue luminescent glow is apparent. This is followed by a sharp rise in light emission as the reaction goes into the second stage, during which detonation occurs. A small increase in pressure accompanies the emission of light in the first stage. At the start of the second stage, light emission and pressure both increase sharply until the reaction is complete.

Experiments have been carried out at NBS on several fuels of various chemical structures. In this way, processes occurring during the first stage of autoignition have been related to the detonation tendencies of the individual fuels. It was found that fuels of low octane number start to burn more readily when compressed as end gas than do those of high octane number. This is in contradiction to one of the tenets of a currently popular theory regarding initiation of combustion. According to this theory, those hydrocarbons having tertiary hydrogen atoms should begin to burn more readily than those with secondary and primary hydrogens. Yet many of the higher-octane fuels containing tertiary hydrogens were found more resistant to burning than those containing only secondary and primary hydrogens.

A correlation was also found between the amount of heat liberated in the first stage of autoignition and the detonation characteristics of the fuel. High-octane fuels did not liberate as much heat as low-octane fuels, and the amount of heat liberated was discovered to be an inverse function of the performance number for several of the fuels studied. These results definitely show that the reactions occurring in the first stage of autoignition have an important bearing on the tendency of the fuel to detonate.

In the first stage a relatively slow oxidation takes place, which is presumed to be a chain reaction. The extent of this reaction and the ease with which it starts are increased by the presence of peroxides, which are known to be easily decomposed to free radicals. The free radicals act as chain initiators and carriers, causing more of the fuel to be burned in this stage of combustion. As a consequence, there is a greater tendency for fuels to detonate if they contain peroxides.

The second stage also appears to be a chain reaction, although probably not of the same type as that occur-

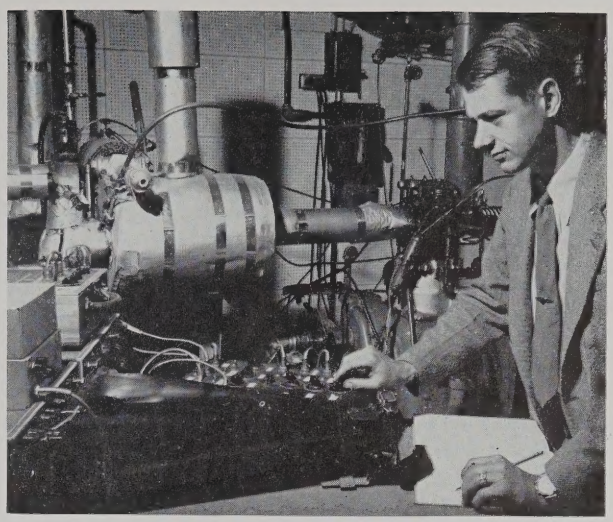


Two curves appear on the oscillogram showing engine knock: A sinusoidal curve representing a normal cycle and an irregular curve in which knock occurs. The latter follows the normal curve until the compressed gas ignites and then rises sharply in two steps, representing the two stages of combustion; in the second stage, burning takes place with explosive violence. The resultant shock wave is reflected back and forth across the combustion space, producing the jagged portion of the curve.

ring in the first stage. The process is visualized as being initiated partly by the effects of the active particles generated in the first stage. If the first stage produces a large concentration of active particles, then the second stage would be expected to progress more rapidly toward detonation. The over-all activity of the particles generated in the first stage may be governed by two factors: one is the population of the particles; the other is the activity of each individual particle, which is probably a function of the temperature and pressure.

Research on the burning mechanism of fuels is continuing at NBS. The ultimate objective of the program is to gain a more thorough understanding of knock and how it is produced. It is expected that results will eventually be obtained that will point the way toward more efficient utilization of automotive fuels, either through the improvement of engines or fuels, or perhaps of both.

For further technical details, see An apparatus for studying autoignition of engine fuels: Results with normal heptane and normal hexane, *by William J. Levedahl and Frank L. Howard, J. Research NBS* **46**, *301 (1951) RP2200.*



In studying the mechanism of engine knock at NBS, a fuel-air mixture is compressed in the cylinder of the test engine, where it ignites spontaneously, causing detonation or knocking. Pressure changes within the cylinder and light emitted by the reaction are shown on oscilloscopes.

Silicone Resin Pigment for Clinical Thermometers

AS the result of research at the National Bureau of Standards, a durable, lasting pigment is now available for marking clinical thermometers. Developed by R. J. Welch and F. W. Reinhart of the NBS organic plastics laboratory, the new marking compound is a silicone resin formulation that withstands cleansing with soap and phenol solutions far better than any other known pigment.

Thermometers used in hospitals must undergo constant immersion in detergent or soap solutions and germicides such as phenol. Loss of pigment due to the action of these cleansing agents has been a major cause of thermometer failure. The Hospital Bureau of Standards and Supplies and the American Hospital Association therefore requested the National Bureau of Standards to make a study of the situation with a view to the development of a pigment that would withstand normal hospital usage. A large number of formulations were investigated, as well as various methods of etching. Finally the new silicone formula was developed, and long-term immersion tests showed that it was the answer to the problem.

The basic ingredient of the NBS marking compound is a silicone resin. To 15 parts by weight of the resin are added five parts of bone black, one part of normal butyl alcohol, and one part of toluene. The mixture, which in the trade is designated "pigment," is ground in a ball or pebble mill; this disperses the bone black in the resin and results in a soft, buttery consistency. If a longer drying time is desired, xylene may be substituted either in whole or in part for the toluene. The bone black in the compound settles partially on standing for 1 to 3 days. However, since the black does not cake, it is readily redistributed by stirring.

A small round brush with short bristles is used to apply the pigment to the thermometer stem. The thermometers are then allowed to dry in the open air at a temperature above 70° F. After 4 days the thermometers may be immersed in a water bath to test their accuracy, and at the end of 2 weeks they may be exposed to disinfectants.

In simulated service tests at the National Bureau of Standards, thermometers marked with the new NBS formulation successfully withstood more than 7 months' continuous or intermittent exposure to a large number of disinfectants, soap solutions, detergents, and other chemicals. All of the commercial marking compounds now in use failed in less than 5 months under the same conditions of exposure. Likewise, all of the experimental compounds tested, except those that were modifications of the NBS silicone compound, failed in less than 5 months.

In connection with this work, NBS has also developed two accelerated service tests that hospitals can use to gage the durability of the markings on the thermometers they purchase. One is a 14-day exposure to a solution of tincture of green soap of a specified concentration. During this period, the thermometers are removed eight times for washing and drying. In the other test, the thermometers are kept in a water solution of phenol for 14-days with the exception of 24 brief removal periods, during which they are rinsed and dried. At the close of each of these immersion tests, the markings should be intact.

IMPROVED design and better bond strength of concrete reinforcing bars have resulted from research conducted at the National Bureau of Standards under a research fellowship of the American Iron and Steel Institute. In addition, the American Concrete Institute has modified its building code requirements for allowable bond stresses in reinforced concrete, and a new standard specification has been adopted by the American Society for Testing Materials. The ASTM specification is the first nationally recognized standard describing the physical characteristics (shape or design) that are required in a reinforcing bar to produce a good bond between the concrete and steel.

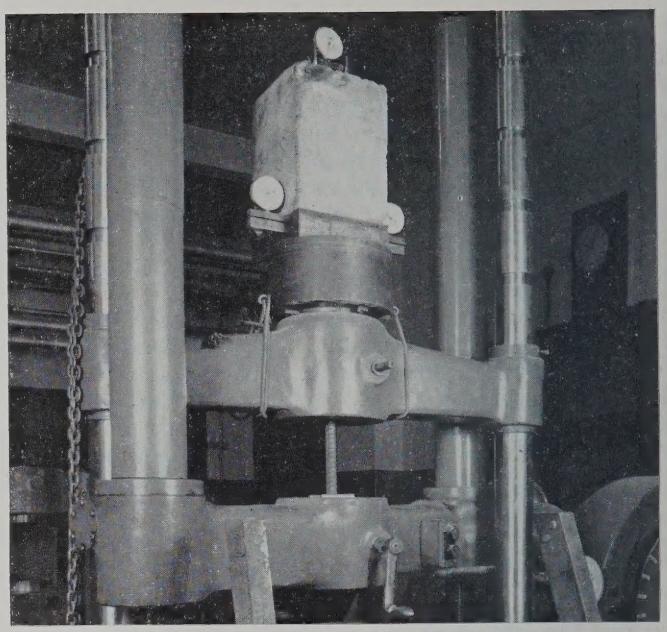
Reinforced concrete construction was introduced by the French about a century ago, and its use has become widespread in this country during the past 50 years. For many years after the introduction of reinforced concrete, the gripping action of the concrete was considered sufficient to create a satisfactory bond or interaction between the concrete and steel and thus to transfer stresses successfully from one material to the other. Plain bars were therefore used for reinforcement.

As the art of using reinforced concrete developed, the sufficiency of plain bars was questioned, because a plain bar offers little resistance to slipping. Various means were then devised to prevent the bars from being pulled out of the concrete, such as anchoring at the ends by "hooking." American engineers soon recognized that this was not the best solution to the problem and began designing bars with ridges, ribs, and other projections (called deformations) that would transfer stress from one material to the other along the length of the bar. These are called deformed bars. The projections are rolled into the surface of the bars in the finishing pass through the rolling mill. Many different patterns have been applied, but until recently bars with the largest deformations were believed to provide the best bond.

For many years there have been standard specifications covering the physical and chemical properties of both plain and deformed bars. Building codes give permissible bond stresses for both types. However, there has been no definition of a deformed bar nor have there been requirements for the deformations. Furthermore, little if any data were available on which to base a scientific definition. Consequently, any bar with arranged projections, however ineffective, has been accepted as a deformed bar.

To aid in solving some of these problems the American Iron and Steel Institute in 1944 established a research fellowship at the National Bureau of Standards. The fellowship is one of several sponsored at various institutions by the Institute's Committee on Reinforced Concrete Research. The primary objectives are to improve the design of concrete reinforcing bars and to develop engineering data that will enable engineers and builders to make more effective use of reinforced concrete.

The first phase of the research program was a comparison of bond strength of the 17 shapes and patterns that were then being rolled. These were cast into blocks of concrete known as pull-out specimens. On

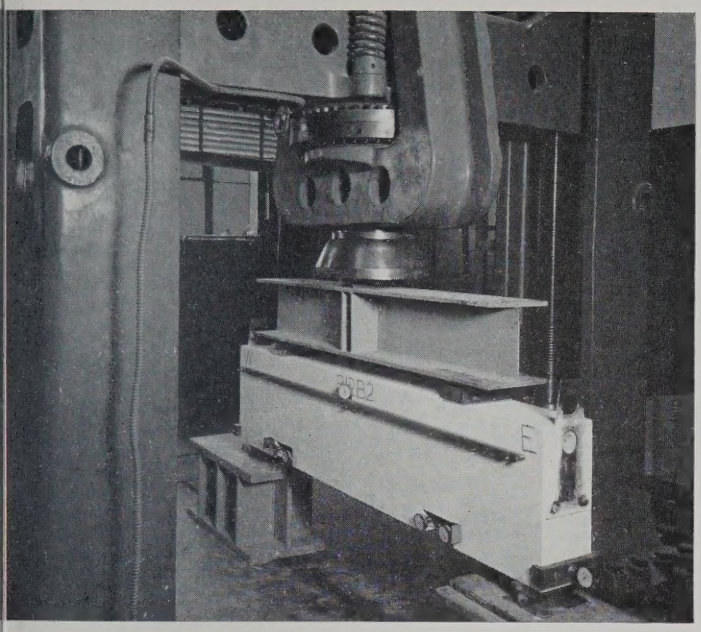


Two types of reinforced concrete specimen, beam (right) and veloped between concrete and reinforcing steel and by which measure strain and slippage of the reinforcing bars at both lo machines. Another gage supported on an aluminum bar mea

Bond Strength of Co

the basis of pull-out tests, those bars that showed the highest comparative bond efficiency were selected for further study. However, several modifications in design were made by the producers because these tests and other research in recent years had demonstrated that the bond strength of reinforcing bars could be increased by better designed deformations. One plain bar and one unimproved bar of a type formerly in general use were also included for comparison. The bars were nominally ½ in. round, ⅞ in. round and 1⅛ in. square. The 1⅛-in. bars, with two exceptions, were round in cross section with areas equal to 1⅛-in. square bars.

Whereas ordinary pull-out tests were used in the early work for comparing the bars, a more elaborate test was devised for the final evaluation of bond strength. Beams 6½ ft. long, 8 in. wide, and 18 in. high were cast, with bars embedded 2 in. from the edge of the beam. Half of the beams were cast with the reinforcing bars at the bottom of the form and half with the bars at the top. (Those with the bars embedded near the top were turned upside down for testing). The purpose of this was to study the effects of embedding the bar at different depths in the mass of concrete. At the same time pull-out specimens (8 by 9 in. in cross section, and 8, 12, and 16 in. long) were prepared, so that a direct comparison could be made between the simpler pull-out test and the beam tests.



ıll-out" (left), were prepared for evaluating the bond that is de-sses are transferred from one material to the other. Dial gages ed and "free" ends as loads are applied in the hydraulic testing es deflection at the center of the beam (right).

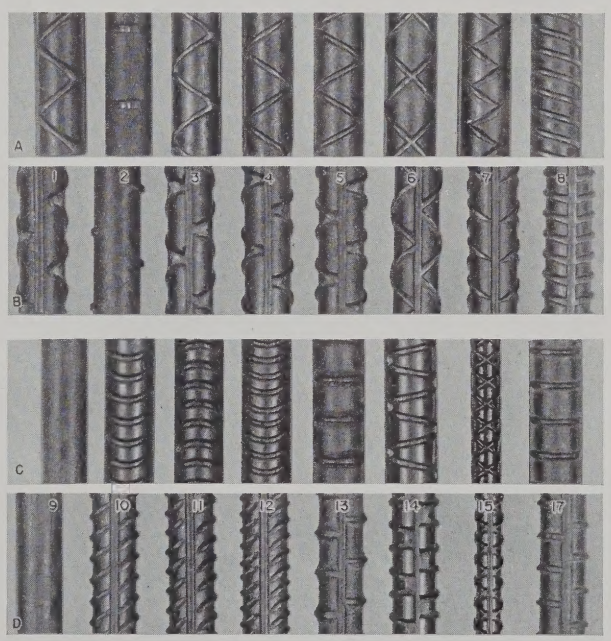
crete Reinforcing Bars

Two notches (6 in. long and 3 in. wide) were placed near the end of each beam. A short length of the reinforcing bar, on which measurements could be made, was thus left exposed. Dial gages attached to the bar gave a direct measurement of strain and slippage of the bar as a load was applied to the beam. The beams were tested in a 600,000-pound hydraulic testing machine and the pull-out tests were made in a 60,000-pound universal hydraulic testing machine. Beams generally failed in bond. The pull-out specimens failed by splitting of the concrete, except when a plain bar was used.

Shortly after this work was started, and on the basis of the preliminary pull-out tests, a "tentative specification for minimum requirements for the deformations of deformed steel bars for concrete reinforcement" was adopted by the American Society for Testing Materials. This made it possible to include bars designed according to the tentative specification in the study. Data from the tests indicated two desirable revisions, and the specifications were adopted as an ASTM standard (designation: A305–49). The standard sets forth definite requirements and methods of measurement; it also specifies the number of test specimens to be taken and the basis for rejection. Requirements are included for angle of deformation, average spacing (distance between deformations on each side of the bar), average height of deformation, and maximum gap between the ends of the deformations. Spacing, height, and gap of deformations are given as percentages of the nominal dimensions of the bar and have been computed and tabulated for each nominal bar size.

The correlation between the results of the beam and the pull-out tests indicated that pull-out tests can give reliable estimates of the bonding efficiency of deformed reinforcing bars. Although the data from the two types of specimens did not always rate the bars in the same order, the differences in ratings were usually too small to be of practical significance; moreover, the relations between load and slip were of similar form, and the general behavior of the bars was similar in the two types of tests.

The plain bar gave the least bond; the old style of deformed bar gave a somewhat higher bond; and the rest of the bars gave still higher values, with those meeting ASTM Specification A305–49 showing the highest bond. The superior performance of the improved types was most marked when the conditions were least favorable for obtaining a strong bond—that is, with the bars in top position as the specimens were cast. As a result of these tests, the American Concrete Institute has revised the provisions of their Standard Building Code Requirements for Reinforced Concrete. The allowable bond stresses of the improved types of deformed bars have been increased by 100 percent and those of plain bars reduced. All bars not conforming to ASTM specification A305–49 are now classed as plain bars. Another important result of the work is that only



Front (*A* and *C*) and side (*B* and *D*) views illustrate the designs of concrete reinforcing bars that were included in the study of bond strength. The work was carried out at NBS under a research fellowship of the American Iron and Steel Institute.

five types of improved bars, as against the original seventeen, are now in commercial production.

The research program of the AISI fellowship is continuing at NBS under the direction of Arthur P. Clark, research associate, who has headed the fellowship since it was established. Studies have now been completed of factors that control the resistance of reinforced concrete to diagonal tension. Work is in progress on the measurement of cracks in reinforced concrete flexural members, relating width of crack to the stress in the reinforcing bar and to other contributing factors. The purpose is to learn how these factors, as well as stress in reinforcing, influence the width of cracks.

For further technical details, see Bond of concrete reinforcing bars, *by Arthur P. Clark, J. Research NBS* **43**, *565 (1949) RP2050; and for details of the earlier work, see* Comparative bond efficiency of deformed concrete reinforcing bars, *by Arthur P. Clark, J. Research NBS* **37**, 399 (1946) RP1755. *These reports are available from Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 10 cents each. ASTM Specification A305–49,* Standard specification for minimum requirements for the deformations of deformed steel bars for concrete reinforcement, *is available from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., 25 cents each;* Building code requirements for reinforced concrete (*ACI: 318–51*) *may be obtained from the American Concrete Institute, 18263 W. McNichols Rd., Detroit 19, Mich. (50 cents).*

NBS Micro Hot-Hardness Tester

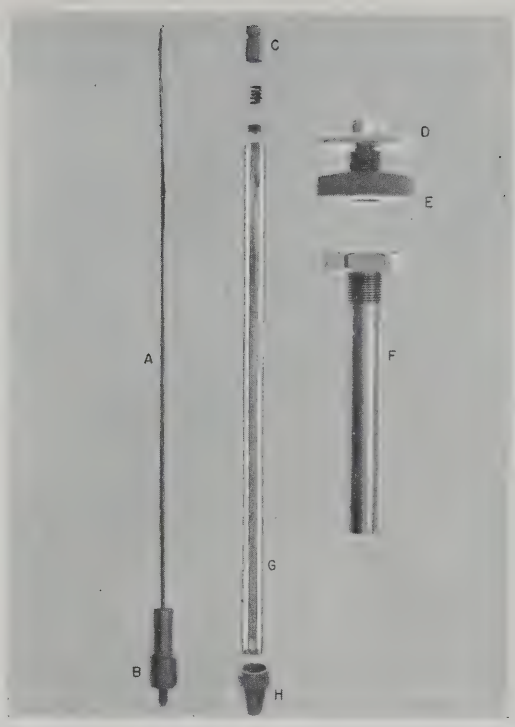
A MICROHARDNESS tester for measuring the hardness of electrodeposits at elevated temperatures has been developed by Dr. Abner Brenner of the NBS electrodeposition laboratory. The new apparatus is based on the diamond-indentation method now used to measure the high-temperature hardness of bulk metals. However, because of the relative thinness of electroplated coatings and their softness at high temperatures, the device has been especially designed to make indentations of microscopic depth under very low loads. Other advantages over previous instruments should also make the tester of value for determining the hot-hardness of bulk metals; in particular, it is expected to find important application in studies of the properties of new types of high-temperature alloys.

The hot-hardness of a metal or alloy is often an important indication of the performance to be expected at high temperatures. Moreover, because a relation usually exists between the hardness of a metal and some of its other mechanical properties, such as tensile strength, data on hardness at various temperatures may also be useful in estimating those mechanical properties that are more difficult to measure.

The NBS microhardness tester for electrodeposited coatings at elevated temperatures employs a furnace of special design, a Vickers diamond indenter (specially mounted and operated to make a microscopic indentation on the hot specimen), and a micrometer device (right) for orienting the specimen so that the indentation can be located more easily for measurement.

Although a number of different devices using indenters of various types have been developed for measuring the hot-hardness of bulk metals, none of these instruments has been found suitable for electrodeposits. In general, the indentation methods produce surface impressions, usually in the form of a four-sided pyramid, whose measurable dimensions vary with depth of marking and thus indicate degree of hardness. The instruments used with bulk metals either employ indenters unsuitable for thin metal coatings or else use heavy loads to produce deep indentations, which would pierce the coatings. For testing electrodeposits, other instruments known as microhardness testers have been developed to produce very shallow indentations under low load, but until now such devices have not been applicable to high-temperature work. NBS therefore undertook to develop a practical method of testing the hot-hardness of electrodeposits. The resulting apparatus overcomes the disadvantages of previous instruments and provides data on electrodeposits at temperatures up to 900° C.

In adapting microhardness testing to high temperatures, it was necessary to use a closed system with an inert atmosphere in order to prevent oxidation of the specimen. Otherwise, the diamond indenter would have to indent a considerable thickness of oxide film before reaching the electrodeposited coating. Also, oxidation occurring after a microindentation had been made would tend to obliterate the impression. Another problem involved the indenter shaft. In order that a light load may be applied accurately, the shaft



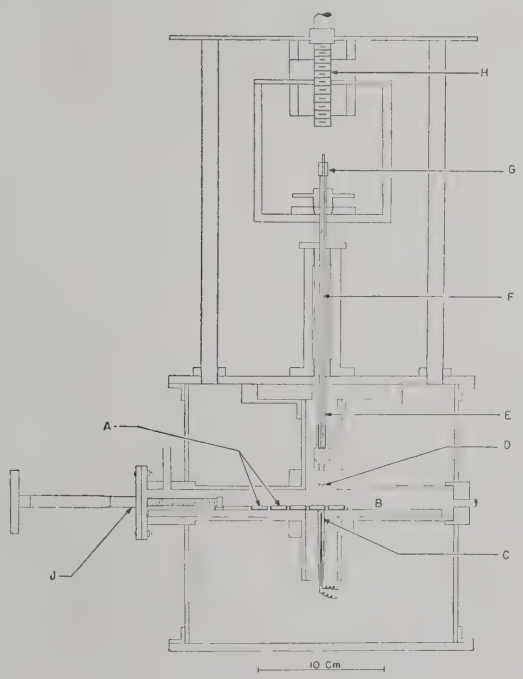
Indenter assembly: *A*, tungsten rod; *B*, fitting that holds the indenter, *H*; *C*, collar for holding tungsten rod in silica capillary *G*; *D*, chuck; *E*, nut; *F*, bearing. The capillary serves as the indenter shaft, moving within bearing *F*. A spring holds the rod under tension to allow for changes in length with temperature changes.

carrying the indenter must move in a bearing with very little friction. Yet the clearance between the rod and the bearing must be very small to prevent the entrance of air.

These problems were met by using in the tester an inert atmosphere slightly above atmospheric pressure and by making the indenter shaft a capillary of fused silica that moves in a dry bearing lubricated with graphite. Clearance between shaft and bearing is only about 0.001 inch, and the gas escapes slowly through this space during the test.

The NBS apparatus consists essentially of a Vickers diamond indenter mounted on the shaft of fused silica; a mechanical device for raising and lowering the indenter; an electric furnace for heating the specimen; and a micrometer device for orienting the specimen under the indenter. Loading mechanism, indenter, and furnace are all enclosed in one compact, self-contained unit.

Before using the apparatus, it is evacuated and flushed out with hydrogen. An inert gas is then passed in under pressure. Specimens are heated, six at a time, in a muffle made of two tubes, one horizontal and one vertical, which intersect to form a cross. The specimens are moved along the horizontal tube of the muffle until one of them comes to rest on an anvil that occupies the lower part of the vertical tube. The indenter is then lowered through the upper part of the vertical furnace tube to make a pyramidal impression on the specimen resting on the anvil.



The muffle was constructed by welding heavy-walled stainless-steel pipes together and is heated with Nichrome wire wound on an Alundum form. The anvil is a solid piece of stainless steel welded into the vertical pipe; a small hole extends to within 0.125 inch of its upper surface to accommodate a thermocouple. The space between the furnace unit and the outer shell of the apparatus is filled with insulation. By making the muffle assembly a single welded unit and by supporting it from a single point, relative motion between various parts due to thermal expansion is minimized.

Because the indenter fitting cannot be anchored directly to the fused silica, it is first attached to a tungsten rod, which passes up through the silica capillary and is held by a collar and set screw. A spring at the top of the rod holds it under continuous tension and thus allows for its expansion with increasing temperature.

The indenter and its shaft are raised and lowered at the rate of 2 centimeters (0.75 inch) per minute by a small motor, which operates a simple screw mechanism similar to that used on the compound rest of a lathe. The vibration of the motor is damped by a mounting of rubber shock absorbers.

The indenter assembly weighs about 200 grams. Additional load can be applied to the indenter by placing weights on top of the assembly. Lower loads for use at elevated temperatures are obtained by increasing the gas pressure in the tester above that of the atmosphere.

Schematic cross section of the NBS microhardness tester: *A*, specimens; *B*, furnace; *C*, anvil for supporting specimens during indentation; *D*, indenter; *E*, indenter shaft; *F*, tungsten rod for attaching indenter; *G*, collar and set screw; *H*, screw mechanism operated by small motor; *J*, micrometer for locating indentation.

The six specimens to be indented in one heat fit into a tray or carriage, which slides on a keyway on the inside of the muffle tube. The carriage is moved along the tube by a stainless-steel micrometer screw, which is plated with cobalt-tungsten alloy to prevent seizing at elevated temperatures. The micrometer serves to locate an indentation within about 0.2 millimeter (0.008 inch) of a desired spot.

Because the indentations are microscopic in size, they are difficult to locate in the small field of a microscope for measurement of their dimensions. For this reason, a fitting has been designed to hold the carriage in a definite position on the stage of a travelling microscope. By setting the microscope stage at the same reading as that on the micrometer when the indentation was made, the impression is easily brought into the field of view.

In addition to its use in measuring the hot-hardness of electrodeposits, the NBS micro hot-hardness tester has several advantages that should make it useful in the testing of bulk metals. For example, when measurements are made at high temperatures, the small loads that are applied to the indenter are less likely to cause the diamond to shift in its mounting than are the larger loads usually applied to hot-hardness testers of this type. The micrometer screw, which permits indentations to be made at specified points and enables them subsequently to be located in the microscopic field, should also be advantageous in the testing of bulk metals as well as electrodeposits.

Lack of a suitable apparatus for comparison has made it impracticable to determine the accuracy of the new tester at high temperatures. However, when it was compared at room temperature with a standard type of microhardness tester using a variety of different kinds of specimens, the agreement was within 4 percent on the average. Reproducibility has been determined by measurements on a molybdenum specimen: in four runs at room temperature, 400°, 600°, and 800° C, the average deviation from the mean hardness at each temperature was less than 4 percent.

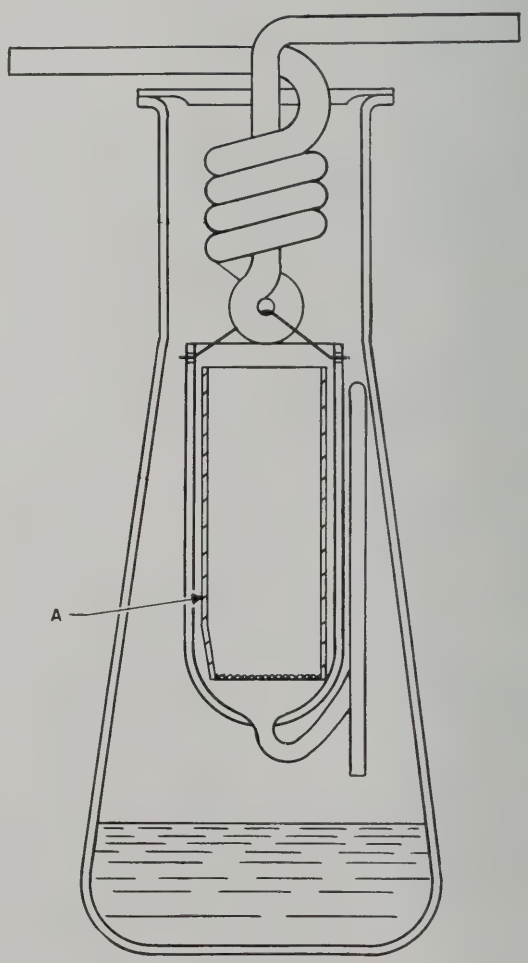
For further technical details, see Microhardness tester for metals at elevated temperatures, *by Abner Brenner, J. Research NBS* **64**, *126 (1951) RP2185.*

Determination of Grease in Leather

A SHORTER and simpler procedure for the removal of grease and oil from leather has been developed by E. W. Zimmerman and Eleanor Pangborn of the National Bureau of Standards. The improved technique, which is based on methods that have long been used in rubber extraction, makes use of a specially designed metal thimble that increases the efficiency of the extraction. This makes it possible to determine grease content on 1- to 3-gram specimens in a relatively short time without sacrificing the accuracy obtained with a 10-gram specimen.

All leather contains a certain amount of grease or oil. In the chemical analysis of leather this grease and oil must be removed and weighed. Ordinarily, about 10 grams of ground leather are extracted in an extractor of the soxhlet type, in which a siphon arrangement intermittently immerses the specimen in fresh solvent. Because a rather large extractor is used, the time required for each cycle is about 15 minutes, and complete removal of grease takes from 5 to 8 hours or more. The leather chemist, however, must often analyze a small amount of material in a limited time. The National Bureau of Standards therefore devised a less time-consuming procedure that could be used with smaller samples. The method reduces the time required for extraction to about 2 hours.

The NBS method utilizes a much smaller, less expensive soxhlet-type extractor as used in rubber extraction. This extractor consists of a block-tin condenser, a 400-milliliter wide-mouth Erlenmeyer flask, and a Pyrex siphon cup suspended in the flask under the con-



A metal thimble, *A*, designed at NBS to replace the conventional cellulose-pulp thimble in a modified soxhlet extraction apparatus, has been found to speed up the removal of grease and oil in leather analysis.

denser. When a solvent such as petroleum ether or chloroform is heated in the flask, the vapor condenses on the condenser and drops onto the specimen within the siphon cup. Periodically the cup fills and then empties by siphon action. In this way freshly distilled solvent is continually brought into contact with the specimen.

In rubber extraction, the specimen is placed directly in the siphon cup or else suspended within it in a cellulose-pulp thimble. However, it was found at NBS that the extraction time for leather is decreased if the specimen is held in a metal thimble instead of the conventional cellulose-pulp thimble. Since the pulp thimble has porous sides, the solvent tends to by-pass the specimen by penetrating the sides of the thimble when the siphon cup is either being filled or discharged. The metal thimble is made of a piece of brass tubing with a 100-mesh screen soldered to the bottom. With this type of thimble, all of the solvent that drips from the condenser must pass over the specimen. A dent in the bottom edge of the thimble prevents the formation of a liquid seal when the thimble is assembled in the siphon cup.

In studies of the method at NBS, four different leathers and two solvents were employed. Data were obtained on extraction time, effect of specimen size, day-to-day variation, and precision for specimens ranging in size from 1 to 10 grams. It was found that 99 percent of the extractable grease and oil can be removed from a 5-gram specimen during a 2-hour period with the rubber extraction equipment and the metal thimble, and that most of the remainder is removed during the third hour. However, a 3-gram specimen is recommended as providing sufficient accuracy for most analyses.

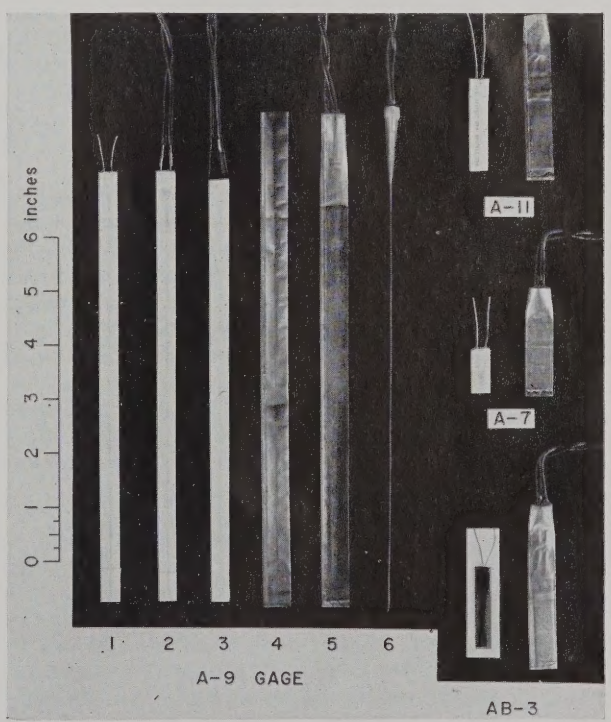
For further technical details, see Determination of grease in leather, *by Elmer W. Zimmerman and Eleanor F. Pangborn, J. Am. Leather Chemists Assoc.* **46**, *342 (1951).*

Strain Gage for Embedment in Concrete

A WATERPROOF internal strain gage, developed by Rudolph C. Valore of the structural engineering laboratory, provides a simple method for determining internal strain, thermal expansion, or drying shrinkage in hardened concrete. A feature of the gage is that it can be embedded in concrete during fabrication of a test specimen or structural member. The development follows an earlier study of the volume changes in concrete during freezing and thawing, in which a mercury-displacement dilatometer was used and which indicated a possible relationship between the resistance of a concrete specimen to frost action and the strains produced during freezing and thawing. The dilatometric method, satisfactory for the exploratory phases of the study, was slow and imposed a limitation upon the maximum size of the specimen and consequently upon the maximum size of the aggregate that could be used in preparing the concrete.

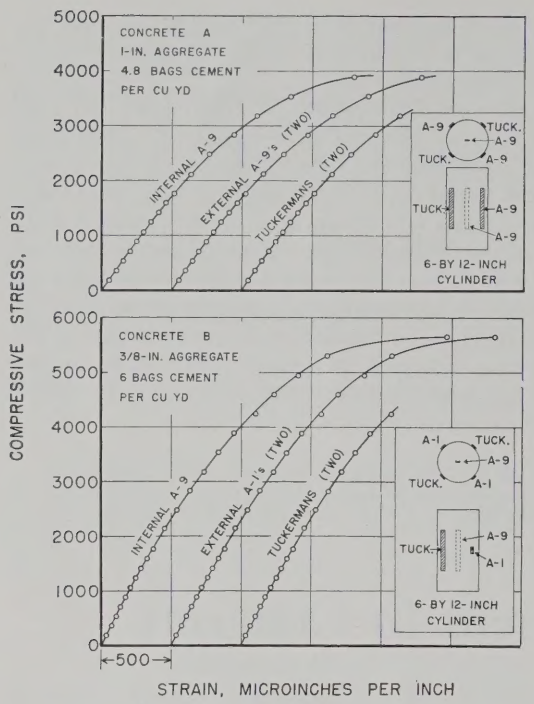
The NBS waterproof gage is a modification of the commercially available "SR–4" bonded wire resistance strain gage [1]. The SR–4, or "postage stamp", gage consists of a loop, grid, or flat helix of 0.001-inch diameter cupro-nickel or other wire "sandwiched" between layers of paper bonded together by a nitrocellulose adhesive, or within a thin Bakelite laminate. As the wire sensing element undergoes extension or shortening, its electrical resistance changes in proportion to the dimensional changes. A bridge-type null-setting indicator supplies the current to be passed through the gage element. When the gage constant (relating change in resistance to change in strain) has been set on the dial, strain may be read directly in micro-inches per inch. Simplicity of use, expendability, and high sensitivity of these gages have been responsible for their wide use in the experimental stress analysis of metals during recent years.

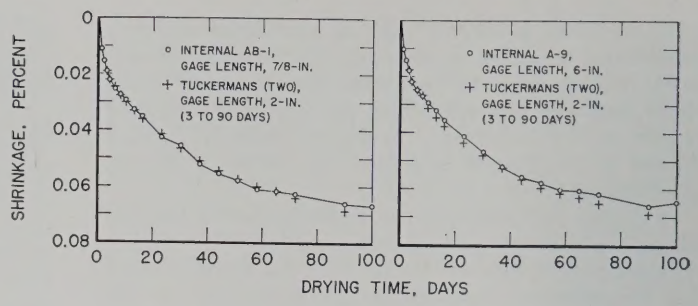
In present concrete theory, there is some uncertainty about the effect of local irregularities in strain upon the operation of gages having gage lengths of 1 inch or



Waterproof internal strain gages are prepared at NBS by bonding SR–4 strain-gage elements to the inner sides of metal-foil envelopes by means of a thermo-setting adhesive and sealing the envelopes with hot cerese wax.

Preparation of waterproof internal strain gages from A–9 (6-inch gage length) resistance elements: (1) Paper-covered A–9 element; (2) rubber-insulated lead wires soldered to element; (3) soldered joint insulated; (4) empty brass foil (0.001-inch) envelope; (5) finished waterproof gage; (6) edge view of finished gage (0.01 inch thick).




INTERNAL AB-1, GAGE LENGTH, 7/8-IN.
TUCKERMANS (TWO), GAGE LENGTH, 2-IN.
(3 TO 90 DAYS)
INTERNAL A-9, GAGE LENGTH, 6-IN.
TUCKERMANS (TWO), GAGE LENGTH, 2-IN.
(3 TO 90 DAYS)
SHRINKAGE, PERCENT
DRYING TIME, DAYS

(Above)

Drying shrinkage data: Waterproof internal strain gages (AB–1 and A–9) and Tuckerman optical lever extensometers. Two concrete prisms (2 by 2 by 12 inches), six bags high-early-strength cement per cubic yard, ⅜-inch aggregate; removed from water, age 10 days; dried 100 days at 70° F., 50-percent relative humidity.

(Left)

Stress-strain data: Waterproof internal strain gages (A–9, 6-inch gage length); external strain gages (A–9 and A–1, 13/16-inch); and Tuckerman optical lever extensometers (6-inch). Concrete A was 28 days old and concrete B (containing high-early-strength cement) 72 days old at time of test.

less, when the gages are located near particles of coarse aggregate. Only one type of SR–4 gage from the hundred or more types now available appears to be of satisfactory gage length for use with concrete; this is the "A–9" gage having a nominal gage length of 6 inches. Since none of the SR–4 gages is waterproof, however, the concrete member to be tested must undergo some drying treatment before the gage can be bonded to the concrete surface. The leakage resistance between sensing element and ground must be maintained high (over 500 megohms), making it necessary to keep the gage perfectly dry at all times. Concrete, initially a wet mixture, loses moisture only gradually upon hardening and is usually re-exposed to moisture in curing or in service; hence the resistance strain gage must be waterproof.

Waterproofing of the present gage is accomplished by bonding an A–9 or other type SR–4 gage to the inner sides of a rectangular metal foil envelope by means of a thermo-setting adhesive. A rolled brass shim, 0.001 inch thick, is the most satisfactory metal foil of those used thus far. The brass shim stock may be bent, folded, or otherwise worked without damage and appears to be impermeable to water vapor in this thickness. Neither steel nor copper in the 0.001 inch thickness has been successfully fabricated into envelopes because they crack when folded over and become permeable.

The metal-encased gage is embedded within a concrete specimen by inserting it at the desired position and orienting it immediately after the fresh concrete has been placed. Transfer of strain from the hardened concrete to the gage is provided by the bond of the cement-water paste in the concrete to the metal foil.

Calibration is not required because the gage constant, as determined by the manufacturer of the gage element, is the same for the waterproof gage.

Seven essential steps are followed in fabricating the NBS waterproof gage. First, the A–9 gages are obtained from the manufacturer without the customary felt covers. The single 6-inch loop of strain-sensitive wire comprising the sensing element for each gage, which is unprotected on one side, is covered by strips of ordinary bond paper bonded by a nitrocellulose cement. Care must be taken to prevent displacement of the strain-sensitive wire during the placing of the paper cover. For most other types of SR–4 gages the elements are covered on both sides as received.

Natural rubber-insulated No. 24 solid copper lead wires in suitable lengths are then lap-soldered to the leads of the gage; the soldered joints are cleaned and covered with electrical tape.

In the next step, a flat rectangular envelope, ½ by 8 inches, is prepared by folding lengthwise and soldering a strip of 0.001-inch brass shim. One end of the flat "tube" thus formed is folded over and soldered closed; the other end is left open for insertion of the gage and the insulated lead wires.

Following this, both sides of the paper-sandwiched gage element are coated with a suitable adhesive [2], and the gage is inserted into the brass envelope with a portion of the insulated leads as well as the soldered joints inside the envelope. The adhesive should be thermo-setting at a temperature below 170° F (preferably at room temperature).

After manipulation to remove entrapped air from the envelope, the gage assembly is placed between two sheets of rubber one-fourth inch thick, backed by plywood boards. Clamps are used to press the flat envelope surfaces together. The clamps near the closed ends of the gages (10 are prepared at one time) are tightened first to move all excess adhesive toward the

open end of the envelope and to make the adhesive layer as thin as possible. After 10 to 15 minutes, the clamps near the open ends are tightened. The pressure exerted upon the gages through the cushioning layers of rubber is much greater than that recommended by the manufacturer, but this procedure has caused no damage to any of the gages produced thus far.

Next, each group of gages, while in the clamping device, is cured for 3 hours at 150° to 160° F (or 48 hours at room temperature). Waterproofing of the gages is completed by filling the space remaining near the open end of the envelope with hot cerese wax, to produce a perfect vapor seal.

The finished gages are stored under water for 1 week with the remote ends of the insulated lead wires kept dry. During this time the gages are periodically checked for leakage resistance between gage element and foil envelope. Should the leakage resistance for any gage decrease during this time, or should it be lower than 500 megohms, the gage is discarded. The proportion of defective gages prepared as described above is almost nil.

Prior to embedment in concrete, each gage is strained and unstrained manually by exerting a tensile force upon the gage several times. This procedure obviates the necessity for a later "shakedown" to stabilize the "zero" of the gage by the customary method of applying and releasing a load upon the test specimen prior to testing.

The steps outlined for waterproofing the A–9 gage are applicable to the other types of SR–4 gages, including the "AB" (Bakelite) as well as the paper-backed "A" types. The effective Young's modulus of elasticity of the gage may be made as low as desired by "building up" the thickness before inserting the gage into the brass envelope. This is accomplished by adding lamina of paper and nitrocellulose or Epon adhesive (all low-modulus materials) to one side of the gage element. The finished gage should be at least 0.01 inch thick so that its effective Young's modulus will not be higher than that of the concrete in which it is embedded—that is, the gage should neither "reinforce" the concrete nor restrain it from movement.

The A–7 or AB–7 gages (¼-in. gage length) are satisfactory for use in neat cement pastes and plaster of Paris; the A–11 (1-in.) and the AB–3 ($^{13}/_{16}$-in.) are satisfactory for mortars. These gages and the A–9 recommended for concretes have low transverse sensitivities and are suitable for use in uniform strain fields (shrinkage and thermal expansion) as well as for measuring uniaxial strains.

The internal gage has performed satisfactorily in stress-strain determinations made upon cylindrical concrete specimens in compression, in measurements of drying shrinkage of concrete prisms dried for 100 days, and in the measurement of linear thermal expansion. Dial-gage length comparators and Tuckerman optical-lever strain gages have been used for evaluating the performance of the internal gages.

Work is now under way to evaluate the stability of the internal gages over longer periods, and to compare directly the performance of the gages with that of the mercury-displacement dilatometer. The testing of mortar or concrete models of structures appears to be a promising field of application for internal strain gages.

[1] *The SR–4 strain gages are manufactured by Baldwin Locomotive Works, Eddystone, Pa.*

[2] *"Epon VI", Shell Chemical Corp., 500 Fifth Avenue, New York 18, N. Y., has proved satisfactory for bonding the gage element to the metal envelope.*

Thirty-Sixth National Conference on Weights and Measures

A RECORD registration of 338 marked the Thirty-sixth National Conference on Weights and Measures, held in Washington on May 22 to 25. Participants included official delegates from 33 States, the District of Columbia, and a number of cities and counties; and representatives of manufacturers, trade associations, railroads, and the Federal Government.

The most important action of the Conference was a complete revision of the Model State Law on Weights and Measures. The model law, published by NBS, is a guide to the States in weights and measures legislation. Some states have incorporated it entirely into their statutes, and many others have adopted portions. Practically every State has thus enacted laws that are based in whole or in part on the model law. This is the first time that it has been completely revised since it was first published in 1907.

A new code for prepackaged-ice-cream measure-containers was tentatively adopted, and the Conference recommended that it be added to NBS Handbook H44 (*Specifications, tolerances, and regulations for commercial weighing and measuring devices*). The code provides definitions; specifications for capacities, design, and marking; and accepted tolerances (excess and deficiency). Ice cream is probably the only commodity that is prepackaged and sold by volume rather than by weight, and whose volume cannot be determined in the field by some convenient, practical method. Under the new code the capacity of the container is accurately defined so that the quantity of ice cream, sherbert, or similar frozen dessert can be determined (on the basis of liquid measure) in advance and at the time of sale.

A resolution was passed suggesting enactment and enforcement of laws governing the sale of commodities by net weight. Nearly half of the States have no laws relating to sale by net weight, and these States are urged to enact such laws. More rigid enforcement is requested of those States that already have net weight laws.

The special committee on railway track scales that was appointed by the president, as a result of a resolution adopted by the Thirty-fifth National Conference in 1950, recommended that NBS continue to operate the railway track scale testing equipment, as it has done for the past 38 years. Their study also indicated the need for at least four additional Master Track Scales, to be located in Alabama, Massachusetts, New York, and Texas. These would provide coverage of the areas that are not directly served by the 19 master scales now in operation.

A scroll in commemoration of the Fiftieth Anniversary of the National Bureau of Standards was presented to the Director, Dr. E. U. Condon, by J. E. Brenton, vice-president, acting on behalf of the Conference. The scroll congratulates NBS "upon its leadership and accomplishments in science and technology, its encouragement and assistance in promoting standardization of measurements and instruments, and, in particular, its achievements in the science of metrology, which have contributed to the public welfare by increasing the accuracy, dependability, and uniformity of weighing and measuring throughout the Nation."

The National Conference is an organization of State and local weights and measures officials and meets under the sponsorship of the National Bureau of Standards. The annual meetings, first held in 1905, serve as a clearinghouse for weights and measures information. Delegates to the Conference develop uniform specifications, regulations, and enforcement practices that are recommended for promulgation in the States. The function of NBS in this activity is advisory only. It has no regulatory powers in the field of weights and measures.

Dr. E. U. Condon, Director of NBS, was reelected president of the Conference. Six vice-presidents were elected: E. R. Fisher (Rhode Island), Erling Hansen (Minnesota), R. D. Thompson (Virginia), J. F. True (Kansas), J. A. Bernard (St. Louis, Mo.), and G. H. Leithauser (Baltimore, Md.). W. S. Bussey, Chief of the NBS Office of Weights and Measures, was named secretary to succeed R. W. Smith, who had been Conference secretary for 11 years and who retired from NBS during the year.

Publications of the National Bureau of Standards

Periodicals

Journal of Research of the National Bureau of Standards, volume **47**, number 2, August 1951 (RP2228 to RP2235, incl.) 75 cents.

Technical News Bulletin, volume **35**, number 8, August 1951. 10 cents.

CRPL–D84. Basic Radio Propagation Predictions for November 1951. Three months in advance. Issued August 1951. 10 cents.

Research Papers

Reprints from Journal of Research, volume 47, number 1, July 1951

RP2220. The role of current distribution in cathodic protection. Homer D. Holler. 10 cents.

RP2221. Multiplets and terms in technetium spectra. William F. Meggers. 10 cents.

RP2222. Properties of beryllium-barium titanate dielectrics. Elmer N. Bunting, George R. Shelton, Ansel S. Creamer, and Bernard Jaffe. 15 cents.

RP2223. Refractivity of lithium fluoride with application to the calibration of infrared spectrometers. Leroy W. Tilton and Earle K. Plyler. 10 cents.

RP2224. Preparation and purification of hydrogen deuteride. Abraham Fookson, Philip Pomerantz, and Edwin H. Rich. 10 cents.

RP2225. Linear thermal expansion of artificial graphites to 1,370° C. Milton D. Burdick, Benson Zweig, and R. Eugene Moreland. 10 cents.

RP2226. The absolute standardization of radioisotopes by 4 π counting. H. H. Seliger and L. Cavallo. 10 cents.

RP2227. A method of gradients for the calculation of the characteristic roots and vectors of a real symmetric matrix. Magnus R. Hestenes and William Karush. 20 cents.

Applied Mathematics Series

AMS12. Monte Carlo method. 30 cents.

AMS15. Problems for the numerical analysis of the future. 20 cents.

AMS16. Tables of $n!$ and $\Gamma(n+\frac{1}{2})$ for the first thousand values of n. Herbert E. Salzer. 15 cents.

Building Materials and Structures Reports

BMS122. Physical properties of some samples of asbestos-cement siding. Cyrus C. Fishburn. 15 cents.

Circulars

C505. Preservation of the Declaration of Independence and the Constitution of the United States. 15 cents.

Handbooks

H45. Testing of measuring equipment. A manual for weights and measures officials. Ralph W. Smith. $1.25.

Publications in Other Journals

Correction factors for the balancing effect of a gas in one leg of a manometer. Howard S. Bean and Francis C. Morey. Instruments (921 Ridge Avenue, Pittsburgh 12, Pa.) **24**, 528 (May 1951).

Microwave components: Precision casting vs electroforming. A. A. Feldmann. Materials and Methods (330 West Forty-second Street, New York 12, N. Y.) **34**, No. 1, 70 (July 1951).

Technetium in the sun. Charlotte E. Moore. Science (1515 Massachusetts Avenue NW., Washington 5, D. C.) **114**, 59 (July 20, 1951).

The construction and operation of thoria resistor-type furnaces. S. M. Lang and R. F. Geller. J. Am. Ceramic Soc. (2525 North High Street, Columbus, Ohio) **34**, 193 (July 1951).

Relations among certain ranges of vector measures. A. Dvoretzky, A. Wald, and J. Wolfowitz. Pacific J. Math. (University of California at Los Angeles, Los Angeles, Calif.) **1**, 59 (March 1951).

Classes of matrices and quadratic fields. Olga Taussky. Pacific J. Math. (University of California at Los Angeles, Los Angeles, Calif.) **1**, 127 (March 1951).

On a Tauberian theorem for Abel summability. Otto Szasz. Pacific J. Math. (University of California at Los Angeles, Los Angeles, Calif.) **1**, 117 (March 1951).

Notes on numerical analysis—4. Relaxation and step-by-step methods. L. Fox. Math. Tables and Other Aids to Computation (2101 Constitution Avenue NW., Washington 25, D. C.) **5**, 92 (April 1951).

Publications for which a price is indicated are available only from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. (Foreign postage, one-third additional.) Reprints from outside journals are not available from the National Bureau of Standards, but can often be obtained from the publishers.

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